others, the centrifugal governor type is adopted; if, however, constant voltage is desired, the electrical governor is used. In the latter the voltage is automatically controlled by the governor, and so accurately can this be done that any desired voltage can be obtained at either full load or no load to within 1 per cent. without altering the governor. Thus, if 5 per cent. rise of voltage is desired at full load in a 100-volt machine, the governor can be adjusted to give 100 volts at no load, and 105 volts at full load. The governor is exceedingly prompt in its action, and large variations of load cause little variation of voltage, thus making the turbine specially suitable for traction purposes.

In both types of governor, one end of a lever is moved up and down either by the centrifugal governor or by a core controlled by a spring, and actuated by a solenoid in shunt with the terminals of the machine. This lever actuates a small valve, which is further moved to a small degree up and down at equal intervals. This small valve, by a steam relay arrangement, actuates the piston, which, in turn, actuates the main admission valve. The result is that at small loads the steam is admitted in a series of equal puffs, thus getting the advantage of the high-pressure steam, and securing great economy at small loads. As the load increases these puffs get longer and longer, until at full load the admission of steam is continuous. The puffs are at such rapid intervals that there is no perceptible variation of the speed of the turbine between each puff. Another advantage of the movement of the valve up and down is that everything is kept in a state of movement, and therefore there is no liability to stick, and all hunting is avoided.

SAND FILTRATION OF PUBLIC WATER SUPPLIES.*

BY R. S. LEA, ASSOC. M. CAN. SOC. C. E.

(Continued from last issue).

The operations which have been described in the foregoing pages are those connected with the carrying on of what is known as continuous sand filtration; and in determining what methods produce the best results, our only test has been the degree of bacterial purification effected. The reason of this is, as we have already seen, that in waters at all likely to be used as public supplies, the actual amount of organic matter is relatively so small as to be of little sanitary significance. Nevertheless, there is a certain degree of chemical purification effected by this process. Analyses of the effluents show a reduction of the dissolved organic matter of from 30 to 60 per cent. This is brought about by the action of the bacteria, which, though existing under adverse conditions, are yet capable of producing this result in the presence of the free oxygen in the water, the amount of which is usually quite sufficient for the purpose. Now, in the case of sewage, which is only very highly polluted water, the amount of free oxygen is very small in comparison with the organic matter present. And it was found, in making experiments on the purification of sewage by passing it through beds of sand, that if air were artificially introduced a very complete reduction of the organic matter would be effected by the bacteria. This was accomplished by working the bed intermittently; that is to say, at regular intervals of time—say 24 hours —the bed was allowed to drain, and fill its pores with the air drawn in after the sewage. After taking this breath the bed rested for a day; then the sewage was again turned on to the surface, preventing the escape of the air which was necessary to provide oxygen for the next 24 hours' purification. The same method used in connection with water is what is termed intermittent filtration. The first filter of the kind was built at Lawrence, Mass., by H. F. Mills, C.E., member of the State Board of Health. Since then, small plants on the same principle have been built at Mt. Vernon, N.Y., and Grand Falls, North Dakota. The results do not seem to indicate any necessity for their use, not being at all superior to those of continuous filters, while the method of operation is not suited to cold climates, and either requires a greater area of bed or a higher rate of filtration. A description of the Lawrence filter may be found in Trans. Am. Soc. C.E., 1893, p. 350.

From what has been said, it will be evident that where the water is at any time liable to turbidity, a settling basin, capable of holding from 12 to 24 hours' supply at least, must be provided Also, in order that the filter may be able to work continuously at a uniform rate, a clear water basin will be necessary of a capacity sufficient to cover the maximum fluctuations in the consumption. If the supply is from a storage reservoir, the filters are placed below the dam, and are, of course, supplied by gravity. But even when the supply is from a river or lake, the topography of the ground often admits of the same economical arrangement. If this is not possible, the water must be pumped into the settling basin by a separate pump of the low lift variety. The extra expense of two pumpings may be almost eliminated if the same station, boiler plant, etc., can be made to serve for both pumps. The total area of filter beds required depends in the first place upon the maximum rate adopted; and, second, upon the area out of use while being scraped and refilled. The higher the rate of filtration the less the total area, and therefore the first cost of the plant. The principal item of expense connected with the operation of this plant is that for scraping; and it is found that the amount scraped for any given quantity of water filtered is independent of the rate. Also, the allowance for the area out of use will not vary with the rate to any extent. Hence an increase in the rate will not by any means produce a proportionate reduction in the cost of filtration. A rate of 3,000,000 gallons per acre of bed in use will give results entirely satisfactory from the standpoint of efficiency, and at a cost which is usually by no means excessive.

The size of the individual beds will depend in part upon the extent of the total area, the smaller plants having necessarily to use smaller beds. A large bed costs less per unit of area than a small one, on account of the proportionately greater length of wall in the latter case. With a large bed it is, however, probably more difficult to obtain a uniform rate of filtration over the whole area. During the winter of cold climates the cost of maintenance is considerably increased by the expense of removing the ice which forms in the bed. It is also difficult to avoid injuriously disturbing the surface of the sand. Beside this, when the water is drawn down the surface sometimes freezes before it can be scraped. On account of such disadvantages as these filter beds should be covered in all cold climates. The best method of constructing these roofs has already been referred to. The proper number, shape, and area of the beds of a system can only be determined for any particular case by careful study of the local conditions, and by making comparative estimates of the different items of cost of construction, maintenance, etc. There will be opportunities for the exercise of considerable ingenuity in the general laying out of the system, the relative placing of its parts, the arrangement of the piping, drains, etc., in order that convenience and economy may be happily combined.

The cost of construction will of course depend on the local circumstances and the kind of materials used. As in all hydraulic work, great care is required in the construction, and the best quality of materials must be used. In the main, it is the same class of work as is required in the building of distributing reservoirs. The following table gives the cost of construction for several European and American filters:

Place.	Cost per Acre.	
	Covered.	Open.
London		\$24,000—\$40,000
Berlin (1884-87)	\$66,000—\$70,000	
Hamburg (1893)		30,500
Warsaw (1885)	78,000	
Zurich (1885)	86,000	
Nantucket, Mass. (1892)		45,500
Hudson, N.Y. (1874-88)		73,000
Ilion (1893)		96,700
Ashland, Wis., (1897)	80,000	
Somersworth, N.H. (1898)	64,000	
Poughkeepsie, N.Y. (1872)		90,000
Poughkeepsie, N.Y. (1896)		41,000

Lindley gives the general cost of continental filters as \$45,000 per acre for open, and \$68,000 for covered. The following figures, giving in detail the bids received February 15th, 1898, for constructing the water filtration plant now in process of construction at Albany, N.Y., will be of more interest. When completed it will be by far the largest plant yet built in America; and in general design and completeness of equipment it will be second to none.. It will consist of a settling basin of 16,000,000 gallons capacity, eight covered filter beds, each with 7-10 of an

*From a paper read before the Canadian Society of Civil Engineers.